Capacity of Interlocking Stub Column with Cement Mortar Infill under Axial Compression Load

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Abstract. This paper presents an experimental investigation on interlocking stub column with cement mortar infill subjected to axial compression load. The interlocking stub column is produced by using load bearing interlocking blocks arranged in vertical direction to form a square shaped column section. The objective of this study is to investigate the compression capacity and failure mode of the column. Six specimens were tested in this study under axial compression load using universal testing machine. From the experiments, all specimens failed in crushing of interlocking blocks. The ultimate load carrying capacity for all tested specimens are in the range of 461.6kN to 577.6kN.

Introduction

Development of appropriate technologies for the production of low-cost building materials of good quality will speed up the provision of affordable urban housing in developing countries. One such technology is the use of Interlocking block [1]. Interlocking block is a masonry unit for building construction as an alternative to replace conventional bricks. Development of interlocking block started in 1980s and can be categorized based on geometry, interlocking mechanism, materials and their applications [2]. The proposed block are formed by mixing the right portion of red soil, sand, water and cement, and will be compressed by hydraulic press machine, to produce a strong and high quality bricks without involving any heating and baking process. These bricks are waterproof and can stand up to 10 tonnes of strength pressure. The interlocking bricks are perfectly fit together beautifully and require minimum maintenance. Construction using interlocking bricks is two times faster than conventional method, lesser number of workers, more economical and environmental friendly. The production of the interlocking bricks will be used in a variety of commercial and residential low rise building applications that can offer superior levels of performance in harsh environment compared to conventional bricks and concrete. The interlocking blocks will be prepared in column element for testing to looking into the compression capacity.

The concept of interlocking bricks is based on the principles that the shape of the bricks are formed with protruding parts, which fit exactly into recess parts in the bricks placed above, such that they are automatically aligned horizontally and vertically. Since the bricks are laid dry, thus no mortar is required and a considerable amount of cement is saved. Each bricks has vertical holes, which with the intention to reduce the weight of the bricks, to allow reinforcement bars to go through the bricks, to act as conduit for electrical and water piping, and to allow liquid mortar/grout to be poured into the holes, which run through the full height of the wall to increase the stability and provide barrier to seepages. A variety of interlocking bricks have been developed during the past years, differing in shape and size, depending on the required strengths and uses. The system developed can be divided into full brick, wall brick and half brick for all standard walls, beam bricks with a channel along the long axis to allow reinforcing steel and concrete can be placed to form lintels or ring beams, and other special bricks such as L-shaped brick and corner sill bricks. Almost any type of building can be constructed with interlocking blocks, the main design constraints being that the plan should be rectangular and all wall dimensions and openings must be multiples of the width of the block type used. All other principles of design and construction, such as dimensioning of foundations, protection against rain and ground moisture, construction of ceilings and roofs, and the like, are the same as for other standard building types. It is advisable to place beam bricks around the building, at window sill height, to install a ring beam. They should also be placed directly above doors and windows to install lintels, and directly below the roof to finish the walls with a ring beam. To increase structural stability, especially in earthquake regions, steel rods or treated kenaf should be inserted in the vertical grout holes, especially at corners, wall junctions and on either sides of openings [3-5].

This paper presents an experimental investigation on interlocking stub column with cement mortar infill subjected to axial compression load. The interlocking stub column is produced by using load bearing interlocking blocks arranged in vertical direction to form a square shaped column section. The aim of this study is to investigate the compression capacity of the column at ultimate limit state. Six specimens were tested in this study under axial compression load using universal testing machine. The ultimate load carrying capacity and the failure mode of the column will be presented in the following section.

Experimental Program

The experimental program consist of two parts, namely material property test and full scale compression test. Material property test involve compressive test of cement mortar, interlocking block and tensile coupon test for reinforcement bars. Full scale compression test on the other hand involve testing of full scale stub column under axial compression load. The cement mortar was prepared in accordance to ASTM C270 [6], mortar type M with cement to sand ratio of 1:3. The expected strength of the mortar is 17.2MPa at 28 days. Another mortar type S with cement to sand ratio of 1:4.5 is also tested in this study with a minimum strength of 12.4MPa at 28 days. The interlocking blocks were supplied by Arca Klasik Group Malaysia as shown in Figure 1.The dimension of the block is 250mm x 125mm x 100mm. The reinforcement bars of Y12 was used in this study as the main reinforcement bars. The purpose of conducting the material test is to ensure that all material used in this study able to achieve the minimum requirement specified in the design standards. Furthermore, the values obtained from the experimental tests could be used in the analytical analysis.

Figure 1: Interlocking block by Arca Klasik Group Malaysia

For full scale compression test, there were 6 specimens tested in this study. Two types of cement mortar, type M and type S were used in this study and each configuration was repeated for 3 samples for laboratory testing. The configuration of the full scale column is shown in Figure 2. The column is fixed to 1 meter height with 4 numbers of Y12 reinforcement bars. The test setup is shown in Figure 3. The column samples were cast in the laboratory of structures and materials, Universiti Teknologi Malaysia and cured for 28 days until design strength has achieved. The column is suitable for testing when the mortar cube has achieve the design strength at 28 days. During setup, the column is move to the test frame using overhead crane. The top and bottom of the column is cover with 50mm steel plate to ensure that uniform pressure is transmitted to the test sample. The load is apply axially to the column specimen through hydraulic actuator with a loading rate of 0.5kN/s. An increment load is apply to the column specimen until the failure achieve and will accept no more load. This load will be recorded as failure load.

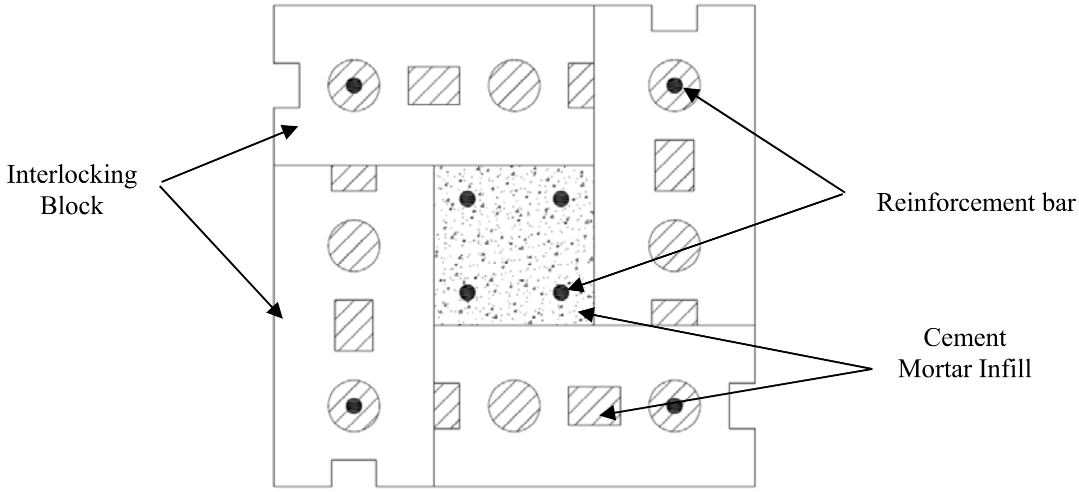


Figure 2: Arrangement of interlocking block and its infill

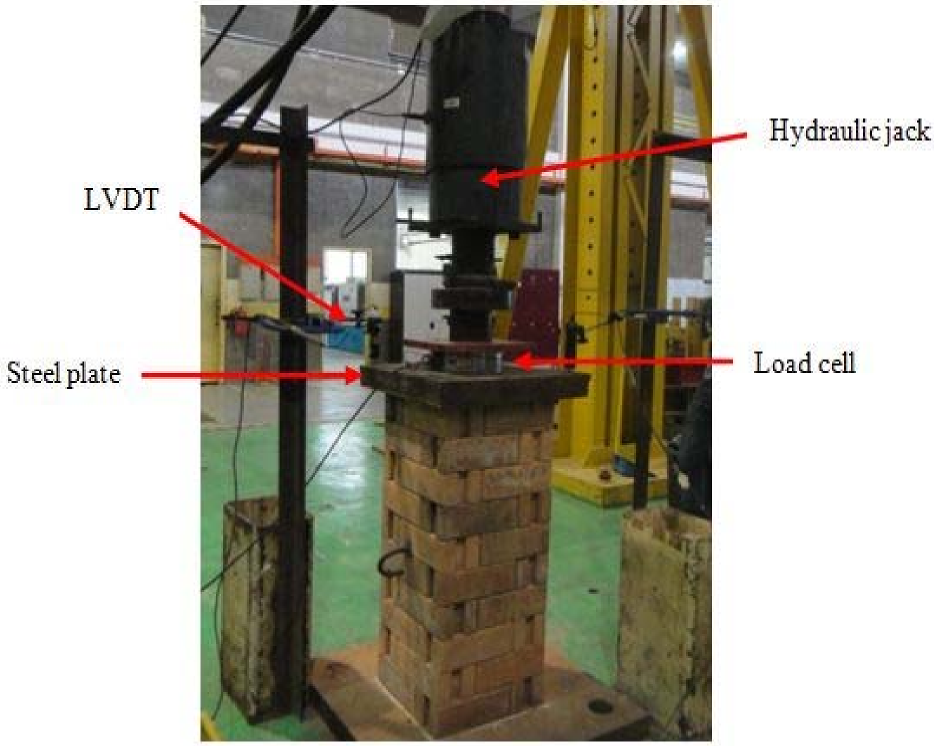


Figure 3: Setting up for column axial load test

Results and Discussion

The results of the material test and column compression test are shown in Table 1 and Table 2 respectively. The failure mode of the column specimen is shown in Figure 4. Generally, the failure modes of the columns were due to crushing of interlocking blocks at failure load. The load-stroke curve for all six column specimens are shown in Figure 5. For Type M mortar, the first crack on column was initiated at 70 kN, 241 kN and 170 kN for specimen1, 2 and 3 respectively. While for Type S mortar, the first crack was found at the loads of 114 kN, 169.5 kN and 149.5 kN for specimen 1, 2 and 3 respectively. Cracks were continuously occurred until the column achieved its ultimate compressive strength. By comparing to the ultimate load capacity, the first crack was found at approximately 30 percent of the maximum load. However, the crack width and length increases with further load increment until crushing of the interlocking blocks occurred at failure load.

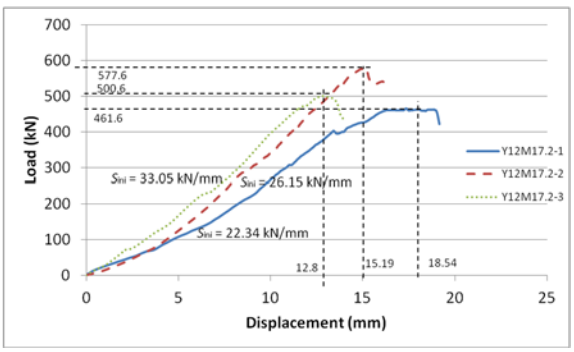
Table 1: Material properties

Specimen	Compressive/ Tensile Strength (MPa)			Mean Value (MPa)	Design Value (MPa)
	1	2	3		
Mortar Type M	**5.87**	**6.75**	**6.71**	**6.44**	**17.2**
Mortar Type S	**6.46**	**5.56**	**5.84**	**5.95**	**12.4**
Interlocking Block	**14.34**	**14.47**	**14.02**	**14.28**	**-**
Y12 reinforcement bar	**609**	**673**	**698**	**660**	**460**

Table 2: Experimental Results for column compression test

Specimen	Max. Load, kN	Max. Displacement, mm	Initial Stiffness, kN/mm
Y12M17.2-1	**461.6**	**18.54**	**22.34**
Y12M17.2-2	**577.6**	**15.19**	**26.15**
Y12M17.2-3	**500.6**	**12.80**	**33.05**
Y12S12.4-1	**520.6**	**19.01**	**17.80**
Y12S12.4-2	**522.1**	**16.31**	**18.36**
Y12S12.4-3	**507.6**	**16.13**	**18.26**

Figure 4: Progressive failure for interlocking block column with Type M mortar

a)


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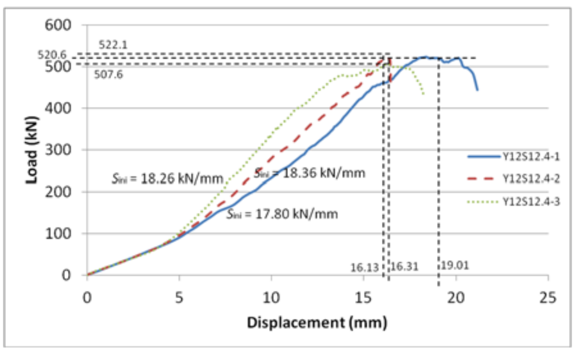

Figure 5: Load Stroke Curves for a) Type M mortar; b) Type S Mortar

Conclusion

The main conclusions that can be drawn from the test program are:

1) As a results from the compression test, interlocking block column using mortar Type M and Type S not giving significant difference in terms of compression capacity. The failure modes are govern by crushing of interlocking blocks.
2) The experimental results showed that compression capacity for all tested sample is in the range of 461kN to 577kN. While the corresponding shortening (stroke) is in the range of 12.8mm to 19mm. The initial stiffness obtained from the load-stroke curves is in the range of 17.8kN/mm to 33kN/mm.

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